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MARKETING MAGNESITE AND ALLIED PRODUCTS

BY

CHARLES L. HARNESS AND NAN C. JENSEN

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

MARKETING MAGNESITE AND ALLIED PRODUCTS[1]

By Charles L. Harness[2] and Nan C. Jensen[3]

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INTRODUCTION

Magnesia (MgO) has a variety of uses, and it has become increasingly important as a war material because of the imperative demand for refractories to line metallurgical furnaces, and because magnesia is used to make the light metal, magnesium, now employed in aircraft and other implements of warfare. Magnesia occurs as an integral part of nearly 60 minerals, but it is extracted commerically from only a small number of them. The present commercial sources are magnesite, brucite, dolomite, raw sea water, sea-water bitterns, and well brines.

MAGNESIA RAW MATERIALS

Magnesite, magnesium carbonate, $MgCO_3$, theoretically contains 47.8 percent MgO and 52.2 percent CO_2. There are two varieties of magnesite, crystalline and cryptocrystalline (dense or amorphous). The latter type, though not so plentiful as the former, is generally purer. It resembles unglazed white pottery in texture, whereas the crystalline variety is generally dark and granular, though the color may vary. The principal domestic deposits of crystalline magnesite are near Chewelah, Stevens County, Wash. (which has supplied most of the magnesite mined in the United States); in the Gabbs Valley area of Nevada (near Luning); and in Llano County, Tex. Cryptocrystalline magnesite occurs principally in California. Magnesite occurrences have also been reported in several other States, including New Mexico, New York, New Jersey, Pennsylvania, Massachusetts, Vermont, and Maryland, but these deposits have not been developed commercially.

Some magnesite is difficult to distinguish from limestone and dolomite visually, but they can be identified by simple chemical tests. Neither magnesite nor dolomite containing no calcium carbonate in solid solution will effervesce in cold hydrochloric acid, whereas both limestone and magnesian limestone will effervesce. The following test will distinguish between magnesite and dolomite. Boil a fragment with dilute sulfuric acid (1 part of sulfuric acid to 6 parts water by volume, made by adding acid to water while stirring). The fragment, if it is magnesite or dolomite, will dissolve slowly. Magnesite gives a clear solution of magnesium sulfate, whereas the calcium in dolomite reacts with the sulfuric acid, leaving a white precipitate of calcium sulfate. If the magnesite sample contains a small percentage of lime, the lime will be precipitated as calcium sulfate, as with dolomite, but the bulk of the precipitate will be much less.

Brucite, magnesium hydroxide, $Mg(OH)_2$, theoretically analyzes 69.1 percent MgO and 30.9 percent H_2O. Crude brucite, because of its higher magnesia content, may be shipped profitably for longer distances than crude magnesite. The only known commercial deposit of brucite in the United States is in the Gabbs Valley or Luning, Nev., area. It is mined there by Basic Refractories, Inc., and shipped to Ohio for calcining. Brucite found in this area "has the appearance of freshly broken laundry soap. The color ranges from white through various shades of yellow to a brown.***. The massive brucite will turn white on exposure to weather within a few months, but the coarsely crystalline material is not similarly affected. Weathered surfaces of brucite are covered by a hard, white, bony coating, which is generally crackled and reflects the underlying crystal structure."[4] Freshly broken brucite is generally soft and waxy, not unlike some varieties of talc. It is slowly soluble in warm hydrochloric acid, without effervescence.

Dolomite, magnesium-calcium carbonate, is theoretically the double salt $CaCO_3.MgCO_3$, but in practice the term dolomite applies also to high magnesian limestone. The theoretical magnesia content of dolomite is 21.9 percent, lime (CaO) 30.4, and carbon dioxide 47.7. Domestic dolomite deposits are widespread, but those being used as sources of magnesium oxide are located in Salinas County, Calif.; near Philadelphia, Pa.; in several areas in Ohio; and in West Virginia. The marketing of raw dolomite will not be discussed in this paper, as the subject is covered in other Bureau of Mines reports.[5]

Dolomite is used both as primary and secondary sources of magnesia. As a primary source it supplies refractory magnesia by the process of the Standard Lime & Stone Co. (p. 10) and by the Pattinson process. The latter method involves dissolving the magnesia content of calcined dolomite as magnesium bicarbonate in reaction vessels containing carbon dioxide gas under pressure. When the remaining solution of magnesium bicarbonate is heated, a basic magnesium carbonate precipitates. In secondary processes, calcined dolomite is used with sea water and well brines to causticize the liquors and also to provide additional magnesia.

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[4] Callaghan, E., Brucite Deposit, Paradise Range, Nevada: Univ. of Nevada Bull., vol. 27, No. 1, January 16, 1933, p. 24.

[5] Bowles, Oliver, and Jensen, Mabel S., Limestone and Dolomite in the Chemical and Processing Industries: Bureau of Mines Inf. Circ. 7169, 1941, 15 pp.; Colby, Shirley F., Occurrences and Uses of Dolomite in the United States: Bureau of Mines Inf. Circ. 7192, 1941, 21 pp.

Raw sea water has an average content of 0.13 percent Mg, a theoretical equivalent of 1 pound of magnesium oxide per 55 gallons of sea water. On the California coast several salt works sell sea-water bitterns (from which the salt, NaCl, has been extracted) to the Westvaco Chlorine Products Corporation, Newark, Calif., as a raw material for the recovery of magnesium oxide. Sea-water bitterns contain 6.0 to 8.7 percent magnesium chloride and 4.2 to 6.1 percent magnesium sulfate.[6] Magnesium oxide is also being extracted from raw sea water by the Northwest Magnesite Co. at Cape May, N. J., for refractory use. In this process the sea water is causticized with calcined dolomite, and the magnesia content of the dolomite is added to that of the sea water. The pioneer producer of magnesia from sea water, however, is Marine Magnesium Products Corporation, with a plant at South San Francisco, Calif., where high-grade pharmaceutical and specialty magnesias have been produced since about 1928.[7]

Magnesium-bearing liquors are rarely sold on the open market, and their marketing is therefore not discussed herein.

Michigan well brines, said to contain about 1.25 pounds of Mg per gallon were used as sources of magnesia for the first time in 1942. The wells are sunk several thousand feet into brine-bearing strata, and the brine is brought to the surface with centrifugal pumps. The Michigan Chemical Corporation plant at St. Louis, Mich., uses calcined dolomite to causticize and enrich well brines for the manufacture of refractory and caustic-calcined magnesia.

Magnesium silicates, including olivine and serpentine, of which there are huge deposits, have not yet been used commercially to produce magnesium oxide, but they are used as sources of other magnesium compounds and may be regarded as potential sources of magnesia.

MINING

Magnesite is mined by both open-pit and underground methods. In Stevens County, Wash., magnesite occurs as huge, steeply pitching lenses in dolomite beds overlain by quartzite. The magnesite is quarried from three large open pits and sent by aerial tramways down the hillside to crushing and calcining units on a rail spur. Quarrying methods also are used to recover magnesite and brucite in Nevada. In California, magnesite generally occurs in veins and is won by underground mining. Dolomite is usually recovered by quarrying. The overburden is removed, the dolomite is broken out by blasting, loaded by power shovels into trucks or quarry cars, and hauled to the surface for washing and crushing.

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[6] Seaton, Max Y., Production and Properties of the Commercial Magnesias: Am. Inst. Min. and Met. Eng., Tech. Pub. 1496, July 1942, 21 pp.

[7] Chesny, H. H., Magnesium Compounds from Ocean Waters: Ind. Eng. Chem., vol. 28, No. 4, April 1936, pp. 383-390.

PREPARATION BEFORE CALCINING

Impurities consisting of magnesium silicate and dolomite veins that interleaf massive Washington magnesite are removed by handpicking after the rock is blasted from the quarry wall. The impurities, it is said, can be distinguished visually with fair certainty. Flotation plants recently introduced at Chewelah, Wash., and near Luning, Nev., are employed to treat magnesite and yield a high-quality magnesite low in fluxes such as silica, iron oxide, and lime. At the Washington flotation plant, raw magnesite is reduced successively in a jaw crusher to 8-inch size, in a gyratory crusher to about 3-inch size, and in a cone crusher to minus 1/4-inch. It is then further reduced in a ball mill to about 65-mesh. Classifiers pass the fines to flotation cells, and the coarse particles are returned to the ball mill. In the 32 flotation cells, magnesium carbonate is separated from impurities, and the relatively pure product passes into a thickener, where excess water is removed, after which the product is calcined. The beneficiated Washington magnesite is used in making magnesia refractory brick, whereas the beneficiated Nevada magnesite is used to make magnesium metal. The magnesite mined by the Sierra Magnesite Co. near Luning, Nev., is pure enough for use without benefication, although the silica content may be reduced by screening out the fines, which are higher in silica than the coarser product. This method is also employed with some of the California magnesites.

The problems encountered in beneficiating magnesite are discussed in several reports.[3]

CALCINING RAW MAGNESITE

Virtually all magnesite (and brucite) is calcined before use, either to render the magnesia content highly reactive (caustic-calcined magnesite) or to render it as unreactive as possible (dead-burned magnesite). The uses of the two calcination products are quite dissimilar. The former is used in plastic magnesia flooring, fertilizers, and various chemicals and for making magnesium metal, whereas nearly all dead-burned magnesia is used in refractories. As calcination is an essential process, the industry has been developed chiefly by a few firms possessing sufficient capital to furnish the necessary kilns and accessories. The smaller magnesite miners sell their raw magnesite to the larger miners, who have calcining equipment.

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[3] Clemmer, J. B., Doerner, H. A., and DeVaney, F. D., Experimental Flotation of Washington Magnesite Ores: Am. Inst. Min. and Met. Eng., Tech. Pub. 1148, 1940, 10 pp.
Sinkinson, Eric, and Michaelson, S. D., Flotation of California Magnesites: Am. Inst. Min. and Met. Eng., Tech. Pub. 733, 1935, 8 pp.
Doerner, H. A., and Harris, Dwight L., Concentration of Low-Grade Magnesite Ores by Flotation: State College of Washington Bull. F-1, 1938, 30 pp.

Rotary kilns and Herreshoff vertical furnaces have superseded older types of kilns. The seven oil-fired kilns installed at Chewelah, Wash., are 125 feet long and either 7 feet 6 inches or 8 feet in diameter, with hot-zone linings of magnesite brick. Each kiln has a capacity of 100 to 150 tons of dead-burned magnesite per day. About 2.2 tons of raw material is required per ton of finished product. The incandescent dead-burned magnesite emerging from the kilns is passed through rotary coolers and then crushed by rolls and sorted by screens into sizes required by the trade. Dust is recovered from kiln gases by means of a Cottrell precipitator. Part of it is returned to the kiln, part is utilized in byproducts, and the part lowest in purity is wasted. Pure magnesite fuses at about 2,800° C., but owing to the fluxes present in Chewelah maintenance-grade magnesite, a calcining temperature of only about 1,560° C. is necessary for crystal growth.

At the Bald Eagle mine of the Westvaco Chlorine Products Corporation, near Gustine, Calif., magnesite is calcined in an oil-fired rotary kiln 100 feet long, 6 feet outside diameter, and 4-1/2 feet inside diameter. The hot zone (4 feet long) is lined with periclase brick. A temperature of 1,760° C. is maintained for periclase production and 800 to 1,200° C. for caustic-calcined magnesite.

Basic Magnesium, Inc., calcines its flotation magnesite to caustic grade in four Herreshoff roasters 60 feet in height and 22 feet in diameter on the theory that this type of kiln is better adapted to calcining fines than the rotary kiln. The Herreshoff roaster consists of a series of circular hearths, one on top of the other. The fines are fed into the top hearth and plowed by revolving arms, so that the material moves toward the central shaft and drops on the hearth beneath. This action occurs successively until the calcined fines are discharged near the bottom of the furnace. Each furnace has a capacity of about 100 tons of caustic-calcined magnesia per day.

A distinction is frequently made in the terms "periclase" and "dead-burned magnesite," though the latter, by definition, includes the former. Periclase is recognized in the trade as magnesia analyzing over 90 percent MgO, calcined at about 1,760° C., whereas dead-burned magnesite analyzes from 65 to 88 percent MgO and is calcined at about 1,560° C. There is some overlapping in analyses of the two grades, as some periclase might analyze as low as 85 percent MgO, in which case it would qualify as a periclase solely because of the higher temperature at which it had been calcined.

SPECIFICATIONS

Crude magnesite. - The main requisite of a marketable crude magnesite is a high magnesia content. Although magnesite theoretically contains 47.8 percent MgO, such purity is never encountered in nature. Any given sample of magnesite is appraised on a calcined basis, either caustic-calcined or dead-burned, as very little crude magnesite is consumed as such without previous calcining. The lowest grade of commercial crude magnesite contains about 43 percent MgO. Permissible impurities are variable, depending on the prospective use of the crude material.

The impurities permissible in raw magnesite which is to be dead-burned are variable, depending on whether the ultimate use is as grain magnesite or as a constituent of magnesite brick. Certain impurities necessary for the manufacture of grain magnesite are permissible in only small quantities in magnesite used in brickmaking. From 4 to 7 percent Fe_2O_3 is desirable in dead-burned grain magnesite for certain brick and maintenance grades. Roll scale or iron ore may be added if not enough iron is initially present. Iron forms such bonding agents as calcium ferrite, $2CaO.Fe_2O_3$, and magnesium ferrite, $2MgO.Fe_2O_3$, the former under conditions of high lime and low silica, the latter when lime is low and silica high. Iron is present in Austrian magnesite in the form of iron carbonate, which decomposes and causes the magnesite to sinter at lower temperatures than if the iron were present as oxide. Silica should be present only in silicate form, which provides a binder for the grains when applied to the furnace bottom. The alumina (Al_2O_3) content generally should not exceed 2.5 percent (dead-burned basis), but alumina is interchangeable to some extent with Fe_2O_3, and in maintenance-grade magnesia a higher content may be allowed, possibly as high as 5 percent, without detriment. For periclase manufacture the maximum Al_2O_3 permissible is 0.3 percent calcined basis. The following analysis is typical of Washington magnesite in the crude state, previous to addition of iron oxide: MgO 42.5, SiO_2 4.2, Fe_2O_3 0.96, Al_2O_3 0.41, CaO 2.76, H_2O 0.06, and CO_2 48.6 percent.

The following analysis is typical of crude magnesite for oxychloride use (crude basis): MgO 43.3, CO_2 48.7, SiO_2 5.7, Fe_2O_3 1.3, Al_2O_3 0.3, and CaO 0.9 percent. On calcining, the CO_2 content is reduced to about 2.2 percent, increasing the other percentages, thus: MgO 82.5, SiO_2 11.0, Fe_2O_3 2.0, Al_2O_3 0.5, and CaO 1.8 percent. Lime in the form of quicklime or hydrated lime is the impurity most detrimental in magnesite for this use, but calcium silicate and calcium carbonate are harmless. Active lime should not exceed 3.5 to 4 percent, crude basis, as it causes excessive expansion in oxychloride cements.

Silica, if present, should be in the form of silicates or as comparatively large grains of SiO_2. Fine silica tends to flux the MgO to form magnesium silicates when the magnesite is calcined.

Maximum impurities desired by Basic Magnesium, Inc., in magnesite for metal use are CaO 1.5, SiO_2 1.0, R_2O_3 (principally $Fe_2O_3 + Al_2O_3$) 1.0 percent, caustic-calcined basis. However, from time to time circumstances have forced the use of less pure material, particularly with respect to lime.

Dead-burned magnesia. - Theoretically, dead-burned magnesia has no ignition loss, but actually it may be about 0.5 percent. Low porosity is an important requisite of brickmaking grades of dead-burned magnesia. The following analysis is typical of dead-burned Washington maintenance-grade magnesia: MgO 80.89, SiO_2 6.95, Fe_2O_3 5.03, Al_2O_3 1.25, and CaO 5.59 percent. A typical analysis of dead-burned Washington brickmaking-grade magnesia is: MgO 83.0, SiO_2 6.6, Fe_2O_3 4.4, Al_2O_3 1.7, and CaO 3.2 percent. Some of the iron content in both analyses is derived from iron ore, which is added to the raw magnesite in a ratio of 2.25 to 100 before calcining, so that the material will sinter at a lower temperature. Number 90 periclase from the Western mine of the Westvaco Chlorine Products Corporation near Livermore, Calif., has the following approximate analysis: MgO 90.9, SiO_2 5.8, Fe_2O_3 1.1, Al_2O_3 0.2, and CaO 2.0 percent. The largest consumer of periclase (for the manufacture of refractories) has furnished the following specification for periclase: Fe_2O_3 0.50 percent maximum, SiO_2 5.50 maximum, CaO 2.00 maximum, Al_2O_3 0.30 maximum, MgO 90.00 minimum, and ignition loss 0.25 maximum.

Caustic-calcined magnesia. - Caustic-calcined magnesia should generally contain 1 to 5 percent $CO_2 + H_2O$, though special-purpose grades may contain as much as 8 percent. It should not be stocked long, as it tends to rehydrate and recarbonate. Time and temperature of calcination should be controlled carefully, because underburned caustic magnesia sets too rapidly in oxychloride cements whereas overburned caustic magnesia sets too slowly and makes a weak cement. Caustic-calcined magnesite is shipped in lump form to distributors where it is ground so that 90 percent passes a 200-mesh screen. The powdered material is then sold to the ultimate consumers.

USES

Crude magnesite. - Relatively small quantities of crude magnesite are consumed without calcining. It is used mainly in making Epsom salt by reaction with sulfuric acid.

Dead-burned magnesia. - As previously mentioned, dead-burned magnesia has only one use - refractories. (A small amount of incompletely calcined dust from dead-burning furnaces is used as fertilizer, but this is generally regarded as caustic-calcined by the trade.) About 88 percent (average for 5-year period 1938-42) of the magnesia produced in the United States is dead-burned. Much of this is crushed and classified for use as grain magnesia, which is used to provide a working hearth in basic open-hearth steel furnaces and for maintenance and repair of the furnaces during the ensuing campaigns. The remainder is used in making brick and cement for basic refractory purposes, mostly in the steel industry.

Magnesia is used in making 8 standard types of bricks, as follows:

A. Fired brick

  1. Made from magnesia, without incorporation of chrome ore

    (a) Low iron oxide content

    (b) High iron oxide content

  2. Magnesia with chrome ore

    (a) Low iron oxide content

    (b) High iron oxide content

B. Unfired brick (same subclassifications as under A)

Most basic brick contain a considerable percentage of chrome ore; generally the brick formula calls for more chrome ore than magnesia. It is estimated that in over-all open-hearth practice, about 15 chrome or chrome-magnesia brick are used to every magnesia brick containing no chrome. About as many brick are used fired as unfired. It is said that the unfired brick are suitable for most purposes after drying.

In constructing the conventional type of basic open hearth, a few inches (about 1-1/2 to 5) of insulation in the form of a fill, concrete, or brick, is placed on the steel shell forming the bottom of the furnace, followed by two or three courses of fire-clay brick and then 7-1/2 to 18 inches of chrome or chrome-magnesia brick. In older practice the subhearth, which was made with magnesia brick, was given a slag wash or a thin covering of magnesia cement to seal the interstices of the brick. In the last 10 years, however, many new and rebuilt open hearths have incorporated a 6 inch layer of plastic chrome ore directly on the subhearth, burnt in at 2,900° F. or higher; this layer gives increased protection against a breakout of metal, should the magnesia working hearth develop seepages. Grain magnesia, mixed with 5 to 25 percent of its weight of slag, is spread in a one-inch layer directly on the subhearth (that is, either on the brick subhearth or the plastic chrome ore subhearth), and the furnace is fired for 24 hours and other layers are added successively until a 6- to 10-inch monolithic working hearth has been built up. If the furnace is properly insulated, the 20 to 70 tons of grain magnesia used as the working hearth can be sintered in 3 to 15 days, during which time 210 to 630 tons of coal or its equivalent may be consumed. After the hearth has been completed, the furnace is "washed out" with molten slag to seal crevices in the bottom. During the ensuing campaigns, grain magnesia, grain dolomite, and proprietary magnesia and chrome ore maintenance materials may be used to patch portions of the hearth that may have floated out or have been damaged by the charge. Dead-burned grain dolomite is by far the principal material used for furnace patching, though considerable raw dolomite is also used. Dead-burned dolomite is preferred to magnesite as a patching material for economic reasons and because of the ease with which dolomite fuses into the furnace bottom and becomes a part of the working hearth.

During the war emergency, rammed bottoms of proprietary magnesia or chrome ore composition have been used instead of the magnesia-slag working hearths described above to get the furnaces into production in the shortest possible time. Basic Refractories, Inc., Cleveland, Ohio, prepares such a magnesia grain by calcining brucite (mined near Luning, Nev.) with dolomite and certain other materials. The resulting refractory analyzes about MgO 65, SiO_2 7.0, Fe_2O_3 7.5, Al_2O_3 1.0, and CaO 18.0 percent.[9] Basic-steel furnace bottoms of this type of refractory, it is claimed, can be rammed to a depth of 15 inches directly on brick much more rapidly than the usual magnesia working hearth can be burned in, evidently an important consideration in wartime. No evidence is yet available as to the life of a brucite-dolomite bottom.

The Standard Lime & Stone Co., Millville, W. Va., produces a grain refractory analyzing MgO 70.0, SiO_2 7.5, Al_2O_3+Fe_2O_3 8.0, and CaO 14.5 percent for use in basic open-hearth maintenance and repair. The material is derived from calcined dolomite by leaching out the more soluble lime with CO_2-free water.

Electric basic-steel furnaces operate at higher temperatures than open-hearth furnaces and require more stable refractories than those used in the open-hearth furnace. Grain magnesia for electric furnaces is necessarily purer (analyzing over 90 percent MgO) than ordinary maintenance grain, so that formation of low-melting glasses between the crystals of periclase in the bottom will be small, that is, just enough to bond the bottom. The present trend is toward the use of fired magnesia brick in the electric furnace, replacing grain bottoms.

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[9] For a discussion of dolomite-magnesia refractories see Schallis, A. H., Dolomite-Base Refractories: Bureau of Mines Inf. Circ. 7227, 1942, 11 pp.

A well-maintained basic open hearth may last 8 to 20 years without a rebuild. Electric furnaces do not generally last nearly so long, but through no fault of the refractories; the bottom is ordinarily torn out and replaced whenever the grade of steel or alloy being made is changed, to avoid contamination.

Magnesia brick are not used in the roofs of American basic open hearths, as the brick are structurally weak at the temperature of the open hearth - about 1,585° C. Silica brick are used instead; but even with silica brick the roof softens at about 1,650° C. Considerable research is in progress to develop a brick that retains structural strength and spalling resistance at temperatures above 1,650° C., and promising experimental results have been obtained with specially prepared brick made from magnesia and chrome ore.

Following is a description of a typical process for making refractory brick from dead-burned magnesia. If the plant receives dead-burned magnesia in lump form, the lumps are reduced in primary and secondary crushers to a predetermined mesh ratio, and the grain thus formed is ground and separated into several screen sizes. The smaller particles help fill voids when the brick is pressed. Various screen sizes of the material, in proper proportion, are weighed out into edge-runner mixing pans, and a little binder, inorganic (such as kaolin) or organic (such as sulfite pitch or dextrin), is added to help hold the brick together before it is dried. The mix is now ready to be pressed. Virtually all magnesia brick are formed in a dry press capable of exerting pressure up to 14,000 pounds per square inch. A four-sided bottomless box resting on a steel platform in back of the machine, fed by a reservoir of mix, moves forward automatically and drops a load of mix into one or more brick-size depressions beneath the poised plungers. The plungers descend and press the prepared mix into brick; the plungers rise, and the brick are automatically ejected. The brick are placed on steel pallets, and the load is trundled to a long oven nearby, where the brick are dried. When dry, the bricks are taken to periodic kilns, stacked on silica-brick supports and fired at 2,880° F. (1,582° C.) for eight days. The kiln is then allowed to cool, and the brick are removed and either loaded directly on cars for shipment or stored. One plant uses a tunnel kiln for firing;[10] a temperature of 3,200° F. (1,760° C.) is maintained in the hot zone, and a kiln car passes through the kiln in about 3 days.

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[10] Housman, G. S., and Seil, G. E., Modern Practice Crystallized in New Tunnel Kiln: Chem. and Met. Eng., vol. 36, No. 6, June 1929, pp. 340-343. (Practice has been modified in several respects since the article was written.)

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Much dead-burned magnesia and periclase is mixed with chrome ore in the manufacture of refractory brick. A smaller quantity is mixed with olivine in making refractories.

Besides being used in basic open-hearth furnaces and basic electric-arc and induction furnaces, magnesia brick and grain are used in the production of several nonferrous metals, particularly copper. The roof of the copper reverberatory furnace, according to Norton,[11] is exposed to a great deal of dust, which fuses and produces a severe slag attack. Silica brick are still used in these roofs in spite of fluxing effect. Within the last few years, chemically-bonded chrome-magnesia brick have been used quite extensively for constructing suspended roofs for the entire furnace arch. These roofs are used almost universally in Canada and are found to last many times longer than the former silica roofs.[12] The brick are also used in side walls at the slag line. Copper converters and holding furnaces are generally lined with magnesia or chrome-magnesia brick. A layer of grain magnesite is placed between the brick lining and the converter shell. In the anode reverberatory furnace, where the copper is further refined, magnesite brick are used in the side walls to a point slightly above the slag line (the bottom generally being ganister rammed on fire-clay brick). Silica brick are generally used above the slag line but chemically bonded and metal-cased magnesia brick also have been used successfully. Magnesia brick have also replaced to some extent the more common silica brick in sections of the anode furnace roof, extending the roof life. In the induction furnace used to melt high-melting-point copper alloys, electrically fused or high-grade kiln-burned periclase mixed with a little sodium silicate has been rammed into the furnace shell.

Magnesia brick are used in lead-refining furnaces at the slag line, where corrosion would otherwise be severe. Magnesia brick are used similarly in lead-drossing furnaces.

Magnesia blocks are used frequently in the hot zones of rotary kilns for cement, lime, dolomite, and magnesite. Steel sheets are inserted between the individual blocks. Though initially more expensive than alumina brick, magnesia brick may prove more economical over a long period.[13]

Magnesia brick are now being used as checker brick in glass furnaces, and brick containing magnesia and chrome ore are used in the ports and uptakes of these furnaces.

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[11] Norton, F. H., Refractories: McGraw-Hill Book Co. Inc., New York, 2d ed., 1942, p. 648.

[12] Chemistry and Industry (London), vol. 61, No. 5, January 31, 1942, p. 88.

[13] Rochow, W. F., Magnesite Linings in Kilns: Rock Products, vol. 41, No. 4, April, 1938, pp. 82-83.

Comber[14] has summarized refractory uses of magnesite.

Caustic-calcined magnesia. - Magnesium oxychloride (Sorel) cements are commonly prepared by mixing a solution of 22° B. (about 20 percent) magnesium chloride with finely ground caustic-calcined magnesia and inert fillers, such as cork and sawdust. The mixture sets in 3 to 4 hours and under the microscope appears as an amorphous mass containing few crystals, homogeneous except for grains of uncombined magnesia. It is thought that this solid solution of MgO in $MgCl_2.XH_2O$ may contain such definite oxychloride compounds as $3MgO.MgCl_2.7H_2O$, $5MgO.MgCl_2.14H_2O$, and $10MgO.MgCl_2.14H_2O$.

The principal use of oxychloride cement during the 1920's, when the industry was at its height, was for outside stucco. This use gradually declined owing to the low weather resistance of the stuccos as then applied, caused in part by improper formulation and poor workmanship. Addition of copper powder to outside oxychloride cements is said to increase weather resistance tremendously.[15]

One square yard of stucco in place is said to weigh about 32 pounds,[16] of which 4.6 is caustic-calcined magnesia; the remainder is magnesium chloride, water in combination, and aggregates.

Oxychloride flooring, the chief use of plastic magnesia at present, contains about 1 pound of magnesia per square foot. Such flooring is of particular value in factories, ship decking, hospitals, and railroad cars, as it is permanent, resilient, fireproof, and can be laid over old or new wooden floors. Also it may be sawed or cut, and attachments may be made to it with nails or screws. In commercial practice the ground plastic magnesia and the magnesium chloride are usually mixed at the point of application.

Miscellaneous uses of oxychloride cement include abrasive wheels, artificial stone, small molded articles such as pipe bowls and casket handles, and fireproof heat-insulating wallboard. For some uses, particularly in wallboard, magnesium sulfate solution may be substituted for magnesium chloride solution.

Two basic processes make use of caustic-calcined magnesia as a raw material in the manufacture of magnesium metal. In one, the magnesia is reduced with finely divided carbon (carbothermic or Hansgirg process, as practiced by Permanente Metals Corporation, using magnesia obtained from raw sea water); in the other the magnesia is reacted with dry chlorine gas in the presence of carbon, producing an anhydrous magnesium chloride. The magnesium chloride is fused and electrolyzed. The second process is used by Basic Magnesium, Inc., at Las Vegas, Nev. Research by the Bureau of Mines indicates that calcined magnesia may be fed directly to the electrolytic cell - a third possible basic process. Fellom has recently reviewed the carbothermic and electrolytic processes.17/

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[14] Comber, A. W., Magnesite as a Refractory: J. B. Lippincott Co., 1937, 114 pp.

[15] Hubbell, D. S., A New Organic Cement and Adhesive: Ind. Eng. Chem., vol. 29, No. 2, February 1937, pp. 123-132.

[16] Ralston, O. C., Pike, R. D., and Duschak, Lionel H., Plastic Magnesia: Bureau of Mines Bull. 236, 1925, p. 7.

Caustic-calcined magnesia from sea-water bitterns is used extensively as a catalyst in the manufacture of synthetic rubber.

The use of magnesia as a fertilizer is growing. It has been found that many soils are deficient in magnesium and that an active grade of magnesia will supply this element satisfactorily. The magnesia used for this purpose is often mixed with commercial fertilizers, not only to furnish magnesium but also to absorb moisture (or excess acid from superphosphate) and otherwise to condition the fertilizer to prevent lumping and produce a free-flowing, easily usable material.

A typical analysis of fertilizer-grade caustic-calcined magnesite is MgO 82.8, SiO_2 9.0, Fe_2O_3 0.8, Al_2O_3 1.2, CaO 3.2, and ignition loss 2.0 percent.

Specially prepared caustic-calcined magnesia is used to clarify and adsorb impurities from petroleum lubricants, dry-cleaning solvents, and other nonaqueous and unreactive fluids. The magnesia is precipitated from magnesium-bearing brines either as $MgCO_3$ or $Mg(OH)_2$ and calcined at a dull red heat (from 325° to 430° C.). The resulting material is agitated with the oil, and then the oil is filtered off, leaving many of the discoloring impurities and much of the carbonaceous matter adsorbed on the magnesia.

Caustic-calcined magnesia has been considered as an agent for recovering sulfur dioxide from flue gases for subsequent use in the manufacture of sulfuric acid. The reactions would be $MgO + SO_2 \longrightarrow MgSO_3$; $MgSO_3 + \text{heat} \longrightarrow MgO + SO_2$.18/

Other uses of caustic-calcined magnesia are in the manufacture of Epsom salt, basic magnesium carbonate ("technical carbonate") for thermal insulation, and glass and in the removal of silica from boiler water.

17/ Fellom, Roy, Jr., Magnesium: Light Metal Age, vol. 1, No. 1, May 1943, pp. 9, 16.

18/ Chemical and Metallurgical Engineering, vol. 49, No. 3, March 1942, p. 151.

PRICES

The prices of magnesia products, with the exception of California dead-burned grain, have remained relatively constant since 1936, as may be seen from table 1. It will be noted that the price of refractory magnesia increases rapidly as the purity of the product improves. This is largely because of the difficulty in sintering the purer grades of magnesia; and exceedingly high temperatures are required to produce artificial periclase, especially from precipitated magnesia.

TABLE 1. - Trade-journal quotations of domestic magnesia products per short ton, 1936-43[1]

	1936	1937	1938	1939	1940	1941	1942	1943 (August)
Dead-burned grain magnesite:								
Washington	$22.00	$25.00	$25.00	$22.00	$22.00	$22.00	$22.00	$22.00
California	25.00	25.00	25.00	25.00	25.00	25.00	40.50	40.50
Artificial periclase:								
94-percent grade	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
90-percent grade	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Caustic-calcined magnesite:								
95-percent grade, white	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
85-percent grade	37.50	37.50	37.50	37.50	37.50	37.50	37.50	37.50

[1] Engineering and Mining Journal (Metal and Mineral Markets) quotations, f.o.b. shipping points in Washington or California.

MAGNESIA SALES, BY SOURCES, IN 1942

TABLE 2. - Magnesia sold or used by producers in the United States in 1942, by kinds and sources

(Quantities and values reported apply to finished products, not raw materials)

Finished products	From magnesite		From brucite, dolomite, and sea-water bitterns		From well brines, dry-lake brines, and raw sea water	
	Short tons	Value	Short tons	Value	Short tons	Value
Caustic-calcined..	19,551	$798,019	(1)	(1)	(1)	(1)
Refractory..........	189,218	4,397,766	(1)	(1)	(1)	(1)
Total	208,769	5,195,785	2/ 93,521	2/ $3,907,396	3/ 7,467	3/ $497,434

1/ Included in "Total."

2/ Includes caustic-calcined and refractory magnesia and magnesia from precipitated carbonate.

3/ Includes caustic-calcined and refractory magnesia and magnesia from precipitated carbonate and from magnesium hydroxide.

SALIENT STATISTICS OF THE MAGNESIA INDUSTRY

TABLE 3. - Salient statistics of the magnesia industry in the United States, 1933-42

Year	Caustic-calcined magnesia			
	1/ Sold by producers		Imports for consumption	
	Short tons	Value	Short tons	Value
1933	4,835	$143,250	1,850	$33,081
1934	4,110	120,525	1,553	36,031
1935	6,049	170,326	1,441	36,076
1936	7,998	221,410	2,196	49,674
1937	10,031	311,326	2,798	62,420
1938	7,400	228,498	1,452	39,551
1939	10,157	310,102	2,218	51,884
1940	16,261	512,607	928	21,301
1941	30,225	1,052,077	3/ 527	3/ 11,538
1942	35,485	1,540,573	(4/)	(4/)

See footnotes on following page.

TABLE 3. - Salient statistics of the magnesia industry in the United States, 1933-42 - Cont'd.

Year	Dead-burned magnesia			
	2/Sold by producers		Imports for consumption	
	Short tons	Value	Short tons	Value
1933	46,919	$880,740	23,509	$341,780
1934	41,953	772,233	22,921	368,014
1935	72,438	1,361,949	24,674	429,830
1936	89,979	1,713,527	42,608	662,567
1937	83,204	1,598,336	56,021	795,047
1938	38,738	730,978	24,990	371,669
1939	86,077	1,699,723	44,420	800,664
1940	140,668	2,802,537	30,951	551,536
1941	201,481	5,052,879	3/36,574	3/802,844
1942	273,661	7,823,963	(4/)	(4/)

1/ 1933-41: Includes caustic-calcined magnesite and caustic-calcined magnesia from sea-water bitterns; 1942: Includes caustic-calcined magnesite and caustic-calcined magnesia from sea-water bitterns, well brines, and raw sea water.

2/ 1933-40: Includes dead-burned magnesite and refractory magnesia from sea-water bitterns; 1941: Includes dead-burned magnesite and refractory magnesia from brucite, dolomite, and sea-water bitterns; 1942: Includes dead-burned magnesite and refractory magnesia from brucite, dolomite, sea-water bitterns, well brines, and raw sea water.

3/ Figures cover January to September, inclusive.

4/ Figures not available for publication.

WORLD PRODUCTION OF MAGNESITE

TABLE 4. - World production of magnesite, 1933-39, by countries, in metric tons1/
(Compiled by B. B. Waldbauer)

Country	1933	1934	1935	1936	1937	1938	1939
Anglo-Egyptian Sudan..	-	-	256	-	-	(2/)	-
Argentina............	-	-	-	-	-	-	50
Australia:							
New South Wales.....	9,512	15,902	15,940	17,459	19,807	19,465	25,207
Queensland..........	152	42	102	102	-	-	-
South Australia.....	205	208	51	118	71	231	382
Victoria...........	6	26	335	219	143	122	119
Western Australia...	-	-	-	-	-	10	-
Canada3/.............	27,158	27,385	27,112	(4/)	(4/)	(4/)	(4/)
China (Manchuria).....	71,376	100,329	225,654	191,568	331,000	5/171,713	5/247,784
Chosen...............	(2/)	3,168	2,410	14,258	37,000	(2/)	(2/)
Czechoslovakia6/......	49,929	58,235	70,838	83,270	92,143	74,707	(2/)
Germany:							
Austria.............	164,331	258,382	300,312	397,776	459,233	7/415,000	7/500,000
Prussia.............	(2/)	11,010	13,818	15,026	21,091	23,860	(2/)
Greece...............	44,719	70,388	93,563	116,106	161,676	168,243	126,786
India, British........	15,450	15,215	17,257	15,716	26,586	26,022	34,107
Italy................	2,187	1,100	1,251	3,153	5,392	6,157	(2/)
Norway...............	2,007	2,500	2,526	3,116	2,096	2,098	2,767
Turkey...............	951	628	1,092	2,247	1,365	846	435
Union of South Africa.	1,495	1,667	1,485	1,694	1,752	2,615	4,022
U. S. S. R.	380,300	482,000	475,000	7/500,000	7/550,000	7/600,000	7/650,000
United States.........	98,145	91,601	160,711	187,894	184,554	88,000	180,511
Yugoslavia (Serbia)...	14,602	25,086	30,225	39,008	41,967	40,779	32,887

1/ Unless otherwise stated, quantities in this table represent crude magnesite mined.
2/ Data not available.
3/ Magnesitic dolomite.
4/ Data for production not available; value reported as follows: 1936, $768,742; 1937, $677,207; 1938, $420,261; 1939, $474,418.
5/ Exports.
6/ Exports, less imports, of crude and sintered magnesite, the sintered being reduced to crude on the basis of 2.1 tons crude to 1 ton sintered.
7/ Estimated production.

IMPORTS19/

TABLE 5. - Dead-burned and grain magnesite and periclase imported for consumption in the United States, 1935-41, by countries

Country	1935	1936	1937	1938	1939	1940	1/1941
Austria:							
Short tons...	12,765	22,496	24,271	2/3,362	(2/)	(2/)	(2/)
Value........	$216,937	$331,890	$351,253	2/$49,000	(2/)	(2/)	(2/)
Canada:							
Short tons...	103	394	333	6	177	346	554
Value........	$8,422	$36,490	$32,098	$563	$17,254	$33,765	$53,970
China:							
Short tons...	--	--	3,421	84	4,341	376	--
Value........	--	--	$42,550	$1,003	$53,860	$4,724	--
Czechoslovakia:							
Short tons...	3,516	13,628	8,940	2/3,236	2/3,567	2/582	(2/)
Value........	$65,129	$201,424	$128,945	2/$53,330	2/$53,902	2/$8,415	(2/)
Germany:							
Short tons...	--	--	(3/)	2/3,329	2/21,279	2/2,313	2/2,102
Value........	--	--	$6	2/$54,860	2/$458,814	2/$39,846	2/$37,914
Hungary:							
Short tons...	--	--	--	--	2/5,081	2/115	2/325
Value........	--	--	--	--	2/$81,506	2/$1,731	2/$4,763
India, British:							
Short tons...	--	--	--	--	11	151	168
Value........	--	--	--	--	$132	$2,146	$2,300
Italy:							
Short tons...	4,083	--	178	--	--	--	--
Value........	$69,884	--	$2,591	--	--	--	--
Japan:							
Short tons...	--	112	1	907	--	--	--
Value........	--	$1,628	$14	$15,143	--	--	--

See footnotes on page 20.

19/ Figures on imports compiled from records of the Department of Commerce.

TABLE 5. - Dead-burned and grain magnesite and periclase imported for consumption in the United States, 1935-41, by countries (Continued)

Country	1935	1936	1937	1938	1939	1940	1/1941
Kwantung:							
Short tons...	--	1,288	17,774	13,249	7,024	25,970	33,425
Value........	--	$14,592	$216,629	$179,135	$84,256	$437,863	$703,897
Norway:							
Short tons...	--	35	--	--	--	--	--
Value........	--	$2,513	--	--	--	--	--
U. S. S. R.:							
Short tons...	4,207	4,655	1,103	817	2,940	1,098	--
Value........	$69,458	$74,030	$20,961	$18,635	$50,940	$23,046	--
Total:							
Short tons...	24,674	42,608	56,021	24,990	44,420	30,951	36,574
Value........	$429,830	$662,567	$795,047	$371,669	$800,664	$551,536	$802,844

1/ Figures are for January to September, inclusive.

2/ Austria has been included with Germany since May 6, 1938. For statistical purposes, trade with the Sudeten area of Czechoslovakia, as far as ascertainable, has been included with Germany since November 10, 1938, whereas trade with the other Czechoslovak provinces occupied by Germany has been included with Germany since March 18, 1939. Trade with the areas of Czechoslovakia occupied by Hungary has been included with Hungary since their respective dates of occupation - December 30, 1938, and March 19, 1939.

3/ Less than 1 ton.

TABLE 6. - Lump caustic-calcined magnesite imported for consumption in the United States, 1934-41, by countries

Country	1934	1935	1936	1937	1938	1939	1940	1/1941
Germany:								
Short tons...	--	--	--	--	(2/)	--	--	--
Value........	--	-	--	--	$171	--	--	--
Greece:								
Short tons...	55	55	224	211	--	--	--	--
Value........	$1,418	$1,417	$5,817	$5,518	--	--	--	--
India, British:								
Short tons...	529	381	896	1,293	359	958	611	439
Value........	$8,071	$6,207	$13,280	$19,799	$6,164	$13,822	$10,460	$6,982
Netherlands:								
Short tons...	23	92	124	22	--	--	24	--
Value........	$669	$1,956	$3,304	$484	--	--	$817	--
United Kingdom:								
Short tons...	11	10	1	--	--	--	--	--
Value........	$542	$276	$152	--	--	--	--	--
Yugoslavia:								
Short tons...	--	15	--	169	258	224	145	--
Value........	--	$390	--	$4,710	$7,557	$5,766	$3,795	--
Total:								
Short tons...	618	553	1,245	1,695	617	1,182	780	439
Value........	$10,700	$10,246	$22,553	$30,511	$13,892	$19,588	$15,072	$6,982

1/ Figures cover January to September, inclusive.
2/ Less than 1 ton.

TABLE 7. - Ground caustic-calcined magnesite imported for consumption in the United States, 1934-41, by countries

Country	1934	1935	1936	1937	1938	1939	1940	1/ 1941
Canada:								
Short tons...	--	--	--	--	--	--	--	61
Value........	--	--	--	--	--	--	--	$2,247
Czechoslovakia:								
Short tons...	--	55	--	--	--	--	--	--
Value........	--	$1,417	--	--	--	--	--	--
Germany:								
Short tons...	3	5	4	5	1	8	--	--
Value........	$278	$672	$214	$267	$56	$370	--	--
Greece:								
Short tons...	89	49	35	234	94	--	--	--
Value........	$1,760	$1,194	$987	$6,412	$2,765	--	--	--
Netherlands:								
Short tons...	374	549	645	632	611	949	135	--
Value........	$10,151	$15,650	$18,049	$18,287	$18,641	$28,606	$5,379	--
United Kingdom:								
Short tons...	67	86	79	60	19	79	13	27
Value........	$2,956	$3,160	$2,796	$2,779	$1,097	$3,320	$850	$2,309
Yugoslavia:								
Short tons...	402	144	188	172	110	--	--	--
Value........	$10,186	$3,737	$5,075	$4,164	$3,100	---	--	--
Total:								
Short tons...	935	888	951	1,103	835	1,036	148	88
Value........	$25,331	$25,830	$27,121	$31,909	$25,659	$32,296	$6,229	$4,556

1/ Figures cover January to September, inclusive.

Producers of magnesia in the United States

Company	Office address	Location of plant	Type of magnesia produced
From magnesite:			
Basic Magnesium, Inc.	Las Vegas, Nev.	Luning, Nev.	Caustic-calcined
Northwest Magnesite Co.	1800 Farmers Bank Bldg., Pittsburgh, 22, Pa.	Chewelah, Wash.	Caustic-calcined, dead-burned
Permanente Cement Co.	Permanente, Calif.	Permanente, Calif.	Caustic-calcined
Westvaco Chlorine Products Corporation	405 Lexington Ave., New York, 17, N. Y.	Gustine, Calif.	Caustic-calcined, dead-burned
Do.	Do.	Patterson, Calif.	Caustic-calcined, dead-burned
Do.	Do.	Livermore, Calif.	Dead-burned
Do.	Do.	Newark, Calif.	Caustic-calcined
From brucite:			
Basic Refractories, Inc.	845 Hanna Bldg., Cleveland, 15, Ohio	Luning, Nev.	Dead-burned
From dolomite:			
Standard Lime and Stone Co.	2000 First National Bank Bldg., Baltimore, 3, Md.	Millville, W. Va.	Dead-burned
Philip Carey Mfg. Co.	Plymouth Meeting, Pa.	Conshohocken, Pa.	Magnesia
Keasbey and Mattison Co.	Butler Ave. & Maple St., Ambler, Pa.	Ambler, Pa.	Magnesia
From sea-water bitterns:			
Westvaco Chlorine Products Corporation	405 Lexington Ave., New York, 17, N. Y.	Newark, Calif.	Caustic-calcined, dead-burned
From well brines:			
Michigan Chemical Corporation	500 N. Bankson St., St. Louis, Mich.	St. Louis, Mich.	Caustic-calcined, dead-burned
From raw sea water:			
Northwest Magnesite Co.	1800 Farmers Bank Bldg., Pittsburgh, 22, Pa.	Cape May, N. J.	Dead-burned
Permanente Metals Corporation	Permanente, Calif.	Moss Landing, Calif.	Caustic-calcined
Marine Magnesium Products Corporation	South San Francisco, Calif.	S. San Francisco, Calif.	Magnesia

BUYERS

Possible buyers of crude magnesite and brucite

Basic Refractories, Inc., 845 Hanna Bldg., Cleveland 15, Ohio.
Meramec Minerals, Inc., 723 Hanna Bldg., Cleveland 15, Ohio.
Northwest Magnesite Co., 1800 Farmers Bank Bldg., Pittsburgh 22, Pa.
Permanente Metals Corporation, Permanente, Calif.
Westvaco Chlorine Products Corporation, 405 Lexington Ave., New York 17, N. Y.

Possible buyers of dead-burned magnesia

Following is an incomplete list of firms operating basic open-hearth steel furnaces that use dead-burned magnesia. Not all of the branch plants of the larger firms are listed, and many firms that operate only a few hearths are not listed at all.

Tennessee Coal, Iron & Railroad Co., Birmingham, Ala. (Hearths at Fairfield, Ala.)
Columbia Steel Co., San Francisco, Calif. (Hearths at Pittsburg, Calif.)
Kaiser Co., Inc., Fontana, Calif.
Colorado Fuel & Iron Corporation, Pueblo, Colo.
Republic Steel Corporation, Cleveland, Ohio. (Hearths at Chicago, Ill.; Cleveland, Ohio; Youngstown, Ohio; and Canton, Ohio)
Wisconsin Steel Co., South Chicago, Ill.
Granite City Steel Co., Granite City, Ill.
Inland Steel Co., Indiana Harbor, Ind.
American Rolling Mill Co., Middleton, Ohio. (Hearths at Ashland, Ky., and St. Louis, Mo.)
Andrews Steel Co., Newport, Ky.
Bethlehem Steel Co., Bethlehem, Pa. (Hearths at Sparrows Point, Md.; Lackawanna, N. Y.; Bethlehem, Pa.; Johnstown, Pa.; Steelton, Pa.; and Seattle, Wash.)
Wheeling Steel Corporation, Wheeling, W. Va. (Hearths at Steubenville, Ohio, and Portsmouth, Ohio.)
National Tube Corporation, Pittsburgh, Pa. (Hearths at Lorain, Ohio.)
Youngstown Sheet & Tube Co., Youngstown, Ohio. (Hearths at Campbell, Ohio.)
Allegheny Ludlum Steel Co., Pittsburgh, Pa. (Hearths at Brackenridge, Pa.)
Carnegie-Illinois Steel Corporation, Pittsburgh, Pa. (Hearths at Clairton, Pa.; Munhall, Pa.; Braddock, Pa.; and Duquesne, Pa.)
Jones & Laughlin Steel Corporation, Pittsburgh, Pa.
Lukens Steel Co., Coatesville, Pa.
Alan Wood Steel Co., Conshohocken, Pa. (Hearths at Ivy Rock, Pa.)
Pittsburgh Steel Co., Pittsburgh, Pa. (Hearths at Monessen, Pa.)
National Steel Co., Pittsburgh, Pa. (Hearths at Weirton, W. Va.)

The following producers of basic refractories are also possible purchasers of dead-burned magnesia:

Basic Refractories, Inc. 845 Hanna Bldg., Cleveland 15, Ohio.
General Refractories Co., 1600 Real Estate Trust Bldg., Philadelphia 7, Pa.
Harbison-Walker Refractories Co., 1800 Farmers Bank Bldg., Pittsburgh, Pa.
E. J. Lavino and Co., 1528 Walnut St., Philadelphia, Pa.

Possible buyers of caustic-calcined magnesia

American Enka Corporation, Enka, N. C.
Armour Fertilizer Works, 816 Walton Bldg., Atlanta, Ga.
Asbestolith Mfg. Corporation, 257 Kent St., Brooklyn, N. Y.
Consolidated Tile & Deck Coverings, 101 Park Ave., New York 17, N. Y.
Dow Chemical Co., Midland, Mich.
Electro-Metallurgical Co., 30 E. 42d St., New York 17, N. Y.
General Electric Co., 1 River Road, Schenectady, N. Y.
Goodyear Tire & Rubber Co., 1144 E. Market St., Akron 16, Ohio.
Hill Brothers Chemical Co., 2159 Bay St., Los Angeles 21, Calif.
Lasting Products Co., 202 S. Franklintown Road, Baltimore, Md.
The Mathieson Alkali Works, Inc., P. O. Box 583, Lake Charles, La.
National Tile & Marble Corporation, 529 W. 48th St., New York, N. Y.
North American Rayon Corporation, P. O. Box 551, Elizabethton, Tenn.
Norton Co., 1 New Bond St., Worcester 6, Mass.
Chas. Pfizer & Co., Inc., 11 Bartlett St., Brooklyn 6, N. Y.
F. E. Schundler & Co., Inc., 504 Railroad St., Joliet, Ill.
F. E. Schundler & Co., Inc., 45-15 Vernon Blvd., Long Island City, N. Y.
Westvaco Chlorine Products Corporation, 405 Lexington Ave., New York, N. Y.